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S. D. Ladner, R. Arnone, R. Vandermeulen, P. Martinolich, A. Lawson, J. Bowers, R. Crout, M. Ondrusek and G. Fargion

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14. ABSTRACT

Navy operational ocean color products of inherent optical properties and radiances are evaluated for the Suomi -NPP VIIRS and MODIS-Aqua sensors. Statistical comparisons with shipboard measurements were determined in a wide variety of coastal, shelf and offshore locations in the Northern Gulf of Mexico during two cruises in 2013. Product consistency between MODIS-Aqua, nearing its end-of-life expectancy, and Suomi-NPP VIIRS is being evaluated for the Navy to retrieve accurate ocean color properties operationally from VIIRS in a variety of water types. Currently, the existence, accuracy and consistency of multiple ocean color sensors (VIIRS, MODIS-Aqua) provides multiple looks per day for monitoring the temporal and spatial variability of coastal waters. Consistent processing methods and algorithms are used in the Navy's Automated Processing System (APS) for both sensors for this evaluation. The inherent optical properties from both sensors are derived using a coupled ocean-atmosphere NIR correction extending well into the bays and estuaries where high sediment and CDOM absorption dominate the optical signature. Coastal optical properties are more complex and vary from chlorophyll-dominated waters offshore. The in-water optical properties were derived using vicariously calibrated remote sensing reflectances and the Quasi Analytical Algorithm (QAA) to derive the Inherent Optical Properties (IOP's). The Naval Research Laboratory (NRL) and the JPSS program have been actively engaged in calibration/validation activities for Visible Infrared Imager Radiometer Suite (VIIRS) ocean color products.

15. SUBJECT TERMS
satellite, SNPP VIIRS, ocean color, optics, validation, vicarious calibration

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Inter-Satellite Comparison and Evaluation of Navy SNPP-VIIRS and MODIS-Aqua Ocean Color Properties

S. D. Ladner[1], R. Arnone[2], R. Vandermeulen[2],
P. Martinolich[3], A. Lawson[1], J. Bowers[3], R. Crout[1], M. Ondrusek[4], G Fargion[5]

[1]Naval Research Laboratory, Stennis Space Center, Mississippi, MS 39529
[2]Dept. of Marine Science, University of Southern Mississippi, Stennis Space Center, MS 39529
[3]QinetiQ North America, Stennis Space Center, Mississippi, MS 39529
[4]NOAA NESDIS, College Park, MD 20740
[5]San Diego State University, CA 92115

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ABSTRACT

Navy operational ocean color products of inherent optical properties and radiances are evaluated for the Suomi–NPP VIIRS and MODIS-Aqua sensors. Statistical comparisons with shipboard measurements were determined in a wide variety of coastal, shelf and offshore locations in the Northern Gulf of Mexico during two cruises in 2013. Product consistency between MODIS-Aqua, nearing its end-of-life expectancy, and Suomi-NPP VIIRS is being evaluated for the Navy to retrieve accurate ocean color properties operationally from VIIRS in a variety of water types. Currently, the existence, accuracy and consistency of multiple ocean color sensors (VIIRS, MODIS-Aqua) provides multiple looks per day for monitoring the temporal and spatial variability of coastal waters. Consistent processing methods and algorithms are used in the Navy's Automated Processing System (APS) for both sensors for this evaluation. The inherent optical properties from both sensors are derived using a coupled ocean-atmosphere NIR correction extending well into the bays and estuaries where high sediment and CDOM absorption dominate the optical signature. Coastal optical properties are more complex and vary from chlorophyll-dominated waters offshore. The in-water optical properties were derived using vicariously calibrated remote sensing reflectances and the Quasi Analytical Algorithm (QAA) to derive the Inherent Optical Properties (IOP's). The Naval Research Laboratory (NRL) and the JPSS program have been actively engaged in calibration/validation activities for Visible Infrared Imager Radiometer Suite (VIIRS) ocean color products.

Keywords: Satellite, SNPP VIIRS, Ocean Color, Optics, Validation, Vicarious Calibration

1. INTRODUCTION

The Navy exploits current and future polar-orbiting ocean color sensors to provide optical properties to support near shore operations[15]. In addition, ocean color products from satellites are also important for monitoring the health and quality of our coastal ecosystems. Coastal ocean color properties can change very rapidly in short period time due to river and terrestrial runoff, tides, winds and other episodic weather events. Being able to derive accurate satellite ocean color properties from multiple satellites daily is important for Navy operations, assimilation into ocean bio-physical forecasting models and coastal environmental and ecosystem decision makers[15]. The existence, accuracy and consistency of multiple ocean color sensors provide multiple looks per day for monitoring the temporal and spatial variability of coastal waters. Multiple shots per day can also be merged to reduce contamination due to clouds, glint, atmospheric failure, etc. Methods have been established to monitor satellite trends and changes in calibration due to sensor degradation and drift using a host of radiometers established on buoys (MOBY)[7,9] and coastal Aerosol Robotic Network Ocean Color (AERONET-OC) sites[12,21]. Inter-sensor calibration is important for the consistency of ocean color properties from multiple satellites when used for operational support and coastal applications and environmental monitoring.

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The objective of this paper is to evaluate the inter-comparison and accuracy of ocean color products derived from MODIS Aqua and Suomi National Polar-Orbiting Partnership (SNPP) VIIRS sensors using the Navy's Automated Processing System (APS)[18]. We will establish the differences in coastal and shelf ocean color properties between the two sensors and evaluate the impacts of applying vicarious gains from The Marine Optical Buoy (MOBY)[6] to the derived estimates of ocean color products. Spatial and temporal variability of bio-optical properties combined with differences in measurement techniques contribute to inconsistencies between remotely sensed and in situ measurements. This evaluation will be done comparing data collected during two field campaigns in the Northern Gulf of Mexico supporting the NASA GEO-stationary Coastal and Air Pollution Events (GEOCAPE) mission and Navy and JPSS program calibration and validation activities during September and November of 2013 to satellite-derived properties (remote sensing reflectance - Rrs, absorption, backscattering and beam attenuation) for both sensors. It is important to note that IOP retrievals are difficult and can reflect the limitations of the algorithms rather than stand as a statement regarding satellite performance. A thorough discussion of deriving IOPS from remote sensing can be found in the IOCCG Report 5, 2006 (http://www.ioccg.org/reports/report5.pdf). VIIRS ocean color products have been compared with MERIS and MODIS retrieved nLw's, chlorophyll and IOP's and have been shown to provide similar quality[2, 3, 4, 14]. As a baseline, literature suggests that mean relative errors ranging from 30 – 70% for IOP retrievals are not uncommon in coastal waters[8, 13].

2. BACKGROUND

VIIRS and MODIS Aqua satellites are used in this study to assess the inter-sensor accuracy of ocean color retrievals which include Remote Sensing Reflectance (Rrs) and Inherent Optical Properties (absorption, backscattering and beam attenuation)[1]. VIIRS and MODIS Aqua Level 1B files (SDR's) coincident with shipboard measurements were obtained from NOAA's Comprehensive Large Array-data Stewardship System (CLASS - http://www.class.ncdc.noaa.gov/saa/products/welcome;jsessionid=EC0D24F6C40611C92AA5AB756D8C2F9A) and processed from Level-1B (calibrated and geo-located Top of Atmosphere radiances) to Level-3 (fully calibrated, atmospherically corrected and mapped) using the Navy's Automated Processing System (APS)[18], the Navy's version of NASA's L2gen software, to obtain remote sensing reflectance (Rrs) at all visible sensor wavelengths and using bio-optical algorithms to provide ocean color products. The standard atmospheric correction was applied using the Gordon/Wang (1994) approach with a NIR iteration[1, 3, 20] to improve retrievals in the coastal ocean by iteratively estimating the NIR contribution by replacing the standard black water assumption (little or no radiance leaving the water in the NIR) that occasionally results in negative nLw's in the coastal waters with high suspended sediment loads. Inherent optical properties were derived from the VIIRS and MODIS Aqua remote sensing reflectances using the Quasi Analytical Algorithm (QAA) [16]. In this study, both VIIRS and MODIS Aqua have been vicariously calibrated by NASA (MODIS Aqua)[11] and NRL (VIIRS)[6] using the MOBY[7,9] located off the Hawaii coast in a blue water stable environment with minimal natural variability (oceanic and atmospheric). MOBY gains were derived using NASA OBPG steps for vicariously generating an average gain and in situ and satellite data collected between January 2012 and April of 2013[6, 11]. Remote sensing ocean color algorithms are based on relationships between remote sensing reflectance (Rrs) and inherent optical properties (IOPs) of absorption and backscattering. It has been shown that small changes in the satellite calibration and normalized water leaving radiance (nLw) or remote sensing reflectance at the water surface can have an impact on derived bio-optical properties between 5-10% in coastal waters[5].

In situ remote sensing reflectance (Rrs) and Inherent Optical Properties (IOPs) were collected during two field campaigns in the Northern Gulf of Mexico in September and November of 2013 in support of the NASA GEOCAPE mission and Navy and JPSS calibration and validation activities. The GEOCAPE cruise took place between September 9 and September 19, 2013 in the Northern Gulf of Mexico off the Louisiana and Texas coast. The *in situ* data was collected in a wide variety of coastal, shelf and offshore locations and measurements of above and below surface radiances and inherent optical properties were provided to NRL courtesy of Mike Ondrusek (NOAA NESDIS) and Zhongping Lee (University of Massachusetts). *In situ* Rrs data were collected using a Satlantic HyperPro free-falling hyperspectral optical profiler (http://satlantic.com/profiler)[19] and a Satlantic above water hyperspectral radiometer (HyperOCR) using a skylight-blocked approach for Rrs at the sea surface[17]. IOP's were collected using a WetLabs Hyperspectral ACS absorption and attenuation meter (http://www.wetlabs.com/ac-s) for absorption and beam attenuation. Satellite retrievals from VIIRS and MODIS were extracted for a single pixel at the *in situ* location. The *in situ* Rrs and IOP's were all considered good if positive and passed all quality flags[19]. Satellite values were screened

using the quality control flags including clouds, glint, land, atmospheric failure and negative radiances in any channel that were provided by the APS processing software. *Figure 1A* shows the mean VIIRS (September 9 -19, 2013) derived total backscatter product using the Quasi Analytical Algorithm (QAA) during the entire cruise time frame and station locations to support the NASA/NOAA GEOCAPE. Station locations are dotted in blue. Total number of valid matchups between *in situ* and satellite Rrs was 25.

A second cruise (*Figure 1B*) was conducted by the Naval Research Laboratory (NRL) on Nov 20, 2013 in which data at station and surface transect using a continuous flow-through system was collected. The flow through Inherent Optical Property (IOP) data included ac-9 (spectral absorption and beam attenuation meter at 9 channels - http://www.wetlabs.com/ac-s) along a 20 km transect from Bay St Louis out to the Gulf of Mexico past Horn Island. These data were spatially bin averaged to the ~1km resolution producing 19 matchups between VIIRS and MODIS Aqua and each retrieved satellite ocean color product (rrs, total absorption and beam attenuation). The hyperspectral remote sensing reflectance (Rrs(λ)) data was collected at 7 station locations using a Analytical Spectral Devices (ASD) handheld hyperspectral radiometer (http://www.asdi.com/products/fieldspec-spectroradiometers/handheld-2-portable-spectroradiometer). Satellite retrievals from VIIRS and MODIS were extracted for a single pixel at the in situ locations. The in situ Rrs (station) and IOP's (flowthru) were all considered good if positive. Satellite values were screened using the quality control flags including clouds, glint, land, atmospheric failure and negative radiances in any channel that were provided by the APS processing software. *Figure 1B* shows the location of 19 flowthru IOP matchups taken from A to B (blue) and 7 Rrs station locations (red) off the coast of Mississippi.

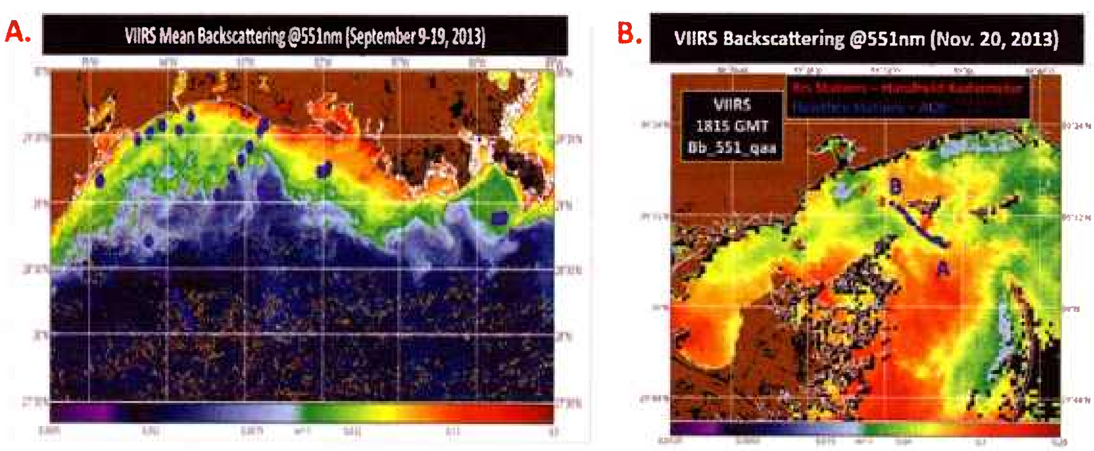
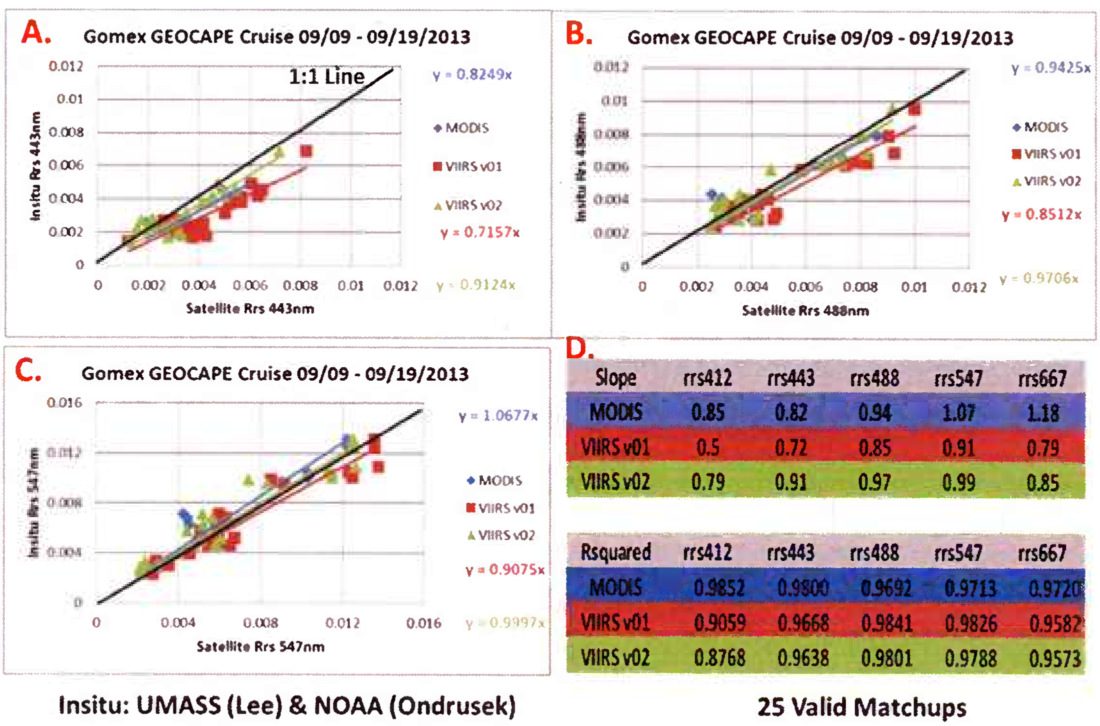


Figure 1. *(A)* Mean VIIRS derived total backscatter product from Quasi-Analytical Algorithm (QAA) at 551nm to support the NASA/NOAA GEOCAPE cruise that took place in the Northern Gulf of Mexico from July 9 to 19, 2013. Station locations are dotted in blue. *(B)* VIIRS derived total backscattering product (QAA) for November 20, 2013 at 551nm and the location of Flowthru Inherent Optical Properties (blue) and Rrs (red dots) data taken off the coast of Mississippi (Mississippi Sound) during the Navy R/V Ocean Color Cruise. Surface flowthru data (IOP's) were binned to ~1km resolution producing 19 available matchups.

3. RESULTS

In this study we (1) compared and evaluated remote sensing reflectance (Rrs(λ)) and Inherent Optical Properties (IOPs(λ)) derived from MODIS and VIIRS with shipboard measurements and (2) evaluated the impacts of applying vicarious gains derived from MOBY to VIIRS by comparing *in situ* Rrs(λ) data collected during the NASA GEOCAPE cruise (September 9 – 19, 2013) and the NRL Cruise (November 20, 2013) in the Northern Gulf of Mexico in coastal and shelf waters. *Figure 2* illustrates matchups between the satellite (MODIS Aqua, NPP VIIRS v01 – no gains, NPP VIIRS v02 – with MOBY gains applied) and *in situ* Rrs at 443, 488 and 547nm (scatter plots) and a table showing the statistics for all wavelengths (412, 443, 488, 547 and 667nm) during the GEO-CAPE cruise which was conducted between September 9 and September 19, 2013. Results show that MODIS and VIIRS derived Rrs(λ) comparisons with

shipboard Rrs are similar and that VIIRS values are better with vicarious gains derived from MOBY applied to the top of atmosphere (TOA) radiances. Rrs estimates for MODIS in comparison with shipboard measurements are overestimated for 412nm (15%), 443nm (18%), 488nm (6%) and underestimated for 547nm (7%) and 667nm (18%). VIIRS Rrs estimates without vicarious gains applied are overestimated for 412nm (50%), 443nm (28%), 488nm (15%), 547nm (9%) and 667nm (21%). The best results for the majority of the wavelengths (443, 488, 547, 667) came from the VIIRS Rrs estimates with a MOBY vicarious gain set applied to the TOA radiances yielding a smaller overestimation at 412nm (21%), 443nm (9%), 488nm (3%), 547nm (1%) and 667 (15%). For all wavelengths except 412nm, The VIIRS derived Rrs(λ) estimates with MOBY gains applied (v02) yielded better regression slopes (closer to the 1:1 line). Both sensors performed well for this coastal/shelf cruise period (Sep. 9-19, 2013). In most cases the satellites overestimated Rrs(λ) in comparison to in situ measurements. The best results for the majority of the wavelengths (443, 488, 547, 667) came from the VIIRS v02 Rrs derived using a MOBY vicarious gain set. R-Squared values for both sensors were very good for all channels greater than 0.87 with a mean average for MODIS (0.98), VIIRS without gains v01 (0.96) and VIIRS with MOBY gains v02 (0.95).



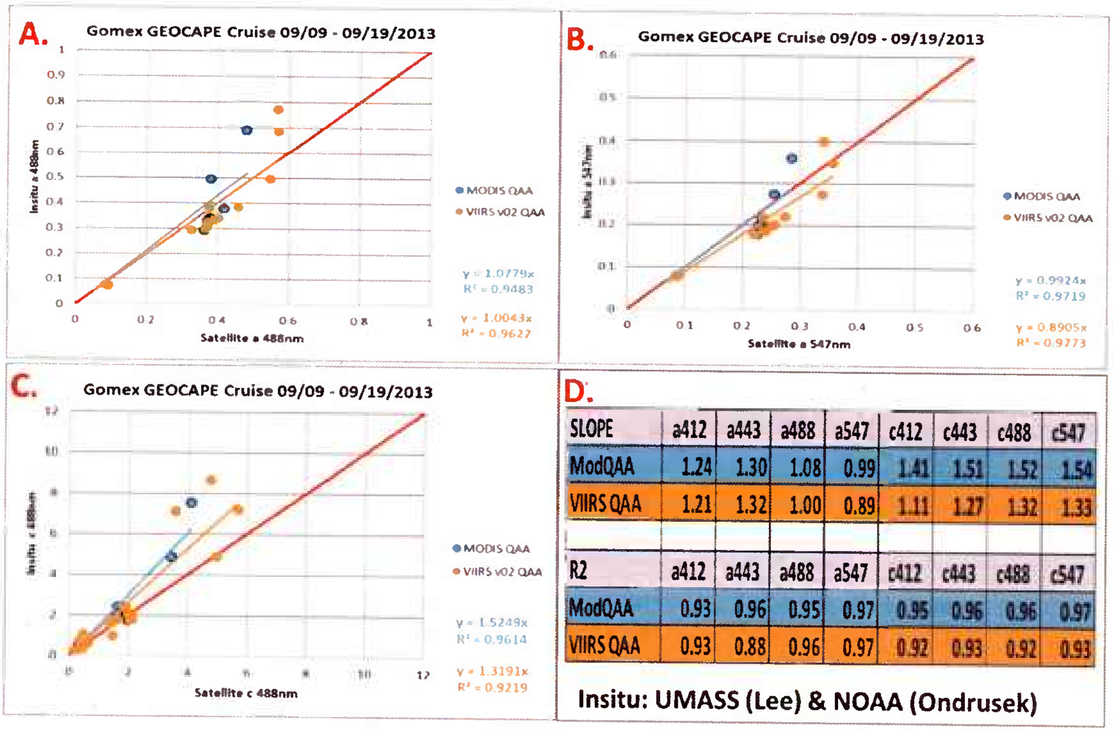
Slope	rrs412	rrs443	rrs488	rrs547	rrs667
MODIS	0.85	0.82	0.94	1.07	1.18
VIIRS v01	0.5	0.72	0.85	0.91	0.79
VIIRS v02	0.79	0.91	0.97	0.99	0.85

Rsquared	rrs412	rrs443	rrs488	rrs547	rrs667
MODIS	0.9852	0.9800	0.9692	0.9713	0.9720
VIIRS v01	0.9059	0.9668	0.9841	0.9826	0.9582
VIIRS v02	0.8768	0.9638	0.9801	0.9788	0.9573

Figure 2. (A) Comparison between satellite derived Rrs at 443nm and *in situ* Rrs (GEO-CAPE cruise: 25 stations) for MODIS (NASA MOBY gains), VIIRS v01 (no gains) and VIIRS v02 (NRL MOBY gains); (B) Comparison between satellite derived Rrs at 488nm and *in situ* Rrs for MODIS (NASA MOBY gains), VIIRS v01 (no gains) and VIIRS v02 (NRL MOBY gains). (C) Comparison between satellite derived Rrs at 547nm and *in situ* Rrs for MODIS (NASA MOBY gains), VIIRS v01 (no gains) and VIIRS v02 (NRL MOBY gains); (D) Regressions Statistics (slope and r-squared) table for matchups between MODIS, VIIRS v01 and VIIRS v02 and *in situ* Rrs measurements.

Figure 3 shows matchups and statistics between VIIRS (NRL MOBY gains – v02) and MODIS (NASA MOBY gains) total absorption and beam attenuation coefficients derived using the Quasi-Analytical Algorithms (QAA) and *in situ* data collected during the September 2013 GEO-CAPE cruise for wavelengths (412, 443, 488 and 547nm) . Results show that satellite derived total absorption (QAA algorithm) comparisons with shipboard measurements are similar between VIIRS v02 and MODIS and that both are performing within know standard errors. The derived MODIS absorption QAA products are approximately 24% (412nm), 30% (443nm) and 8% (488nm) too low and 1% (547nm) too high as

compared to the ac-9 measurement. In comparison, the VIIRS v02 absorption retrieval performs similar to that of MODIS producing differences with measured total absorption coefficient that are approximately 21% (412nm), 32% (443nm) and 0.4% (488nm) too low and 11% (547) too high. For the beam attenuation coefficient matchups, the MODIS and VIIRS v02 both produce higher errors than the absorption at all channels with VIIRS v02 giving better results. The higher errors in beam attenuation could be associated with the backscattering to scattering ratio used in satellite conversions for beam attenuation (Petzold). MODIS is approximately 41% (412nm), 51% (443nm), 52% (488nm) and 54% (547nm) too low as compared to the insitu measurements where VIIRS is approximately 11% (412nm), 27% (443nm), 32% (488nm) and 33% (547nm) to low. The mean error over all four wavelengths for beam attenuation is 49.5% for MODIS and 25.75% for VIIRS. R-Squared values for both sensors were very good (greater than 0.87) for all channels with a mean average over all channels for MODIS (0.98), VIIRS v01 (0.96) and VIIRS v02 (0.95). R-squared from the matchup regressions are very good with a MODIS mean r-squared 0.95 for absorption and 0.96 for beam attenuation. Similarly the r-squared from VIIRS v02 are also reasonably good with a mean of 0.94 for absorption and 0.93 for beam attenuation.



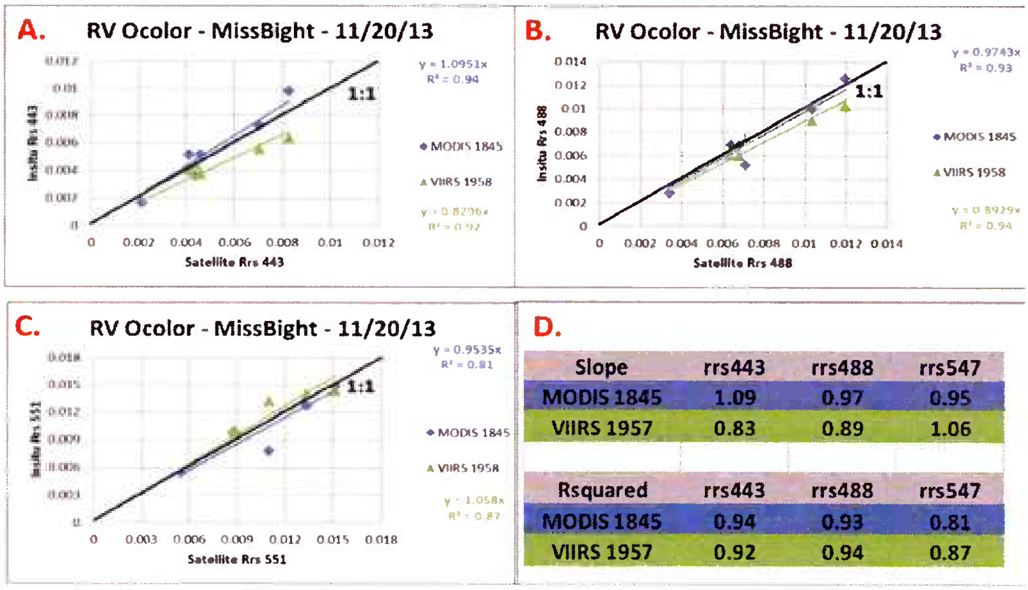
SLOPE	a412	a443	a488	a547	c412	c443	c488	c547
ModQAA	1.24	1.30	1.08	0.99	1.41	1.51	1.52	1.54
VIIRS QAA	1.21	1.32	1.00	0.89	1.11	1.27	1.32	1.33
R2	a412	a443	a488	a547	c412	c443	c488	c547
ModQAA	0.93	0.96	0.95	0.97	0.95	0.96	0.96	0.97
VIIRS QAA	0.93	0.88	0.96	0.97	0.92	0.93	0.92	0.93

Insitu: UMASS (Lee) & NOAA (Ondrusek)

Figure 3. (A) Comparison between VIIRS v02 and MODIS total absorption at 488nm derived from the QAA algorithm and *in situ* total absorption (GEO-CAPE cruise); (B) Comparison between VIIRS v02 and MODIS total absorption at 547nm derived from the QAA algorithm and in situ total absorption (GEO-CAPE cruise); (C) Comparison between VIIRS v02 and MODIS beam attenuation at 488nm derived from the QAA algorithm and in situ beam attenuation (GEO-CAPE cruise); (D) Regressions Statistics (slope and r-squared) table for matchups between MODIS, VIIRS v01 and VIIRS v02 and *in situ* total absorption and beam attenuation measurements for channels 412, 443, 488 and 547.

Figure 4 illustrates matchups between the satellite (MODIS Aqua, NPP VIIRS v02 – with MOBY gains applied) *and in situ* Rrs at 443, 488 and 547nm (scatter plots) and a table showing the statistics for all wavelengths (443, 488 and 547) during the NRL cruise which was conducted on November 20, 2013 in the Mississippi Sound out from the Bay of St. Louis. Results show that MODIS and VIIRS derived Rrs(λ) comparisons with shipboard Rrs are similar and that MODIS estimates are slightly better. Rrs estimates for MODIS in comparison with shipboard measurements are underestimated for 443nm (9%) and overestimated for 488nm (3%) and 547nm (5%). VIIRS Rrs estimates with a MOBY vicarious gain set applied produced larger overestimation at 443nm (17%) and 488nm (11%) and

underestimation at 547nm (6%). Errors for this cruise in the 443, 488 and 547nm channels were slightly higher than the GEO-CAPE cruise. For all three wavelengths MODIS derived Rrs produced better regression slopes (closer to the 1:1 line). Both MODIS and VIIRS performed extremely well during the NRL cruise. R-Squared values for both sensors were very good for all channels greater than 0.81 with a mean average for MODIS (0.89) and VIIRS with MOBY gains v02 (0.91).

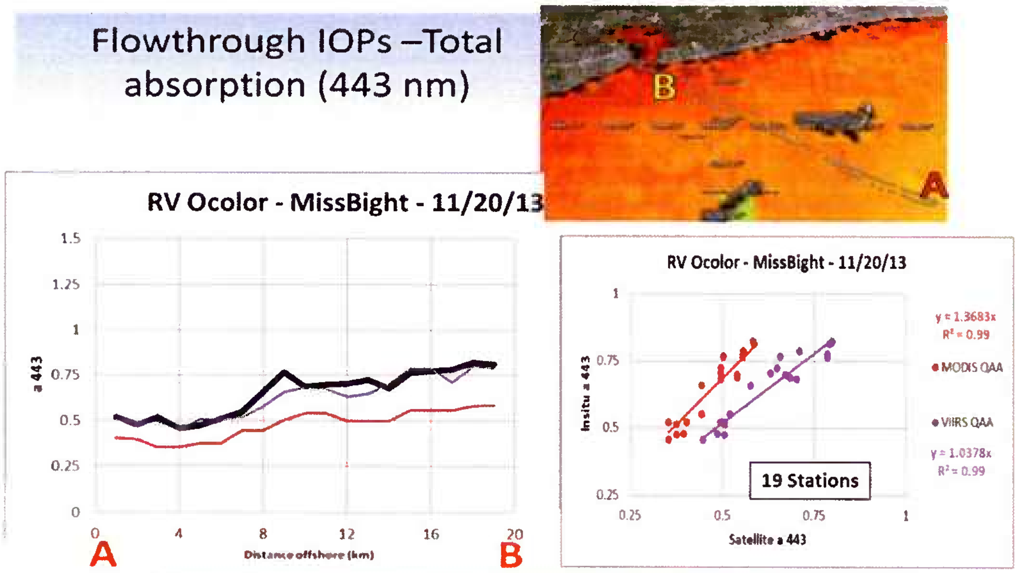


Slope	rrs443	rrs488	rrs547
MODIS 1845	1.09	0.97	0.95
VIIRS 1957	0.83	0.89	1.06

Rsquared	rrs443	rrs488	rrs547
MODIS 1845	0.94	0.93	0.81
VIIRS 1957	0.92	0.94	0.87

Figure 4. (A) Comparison between satellite derived Rrs at 443nm and in situ Rrs (NRL cruise: 7 stations) for MODIS (NASA MOBY gains) and VIIRS v02 (NRL MOBY gains); (B) Comparison between satellite derived Rrs at 488nm and in situ Rrs for MODIS (NASA MOBY gains) and VIIRS v02 (NRL MOBY gains). (C) Comparison between satellite derived Rrs at 547nm and in situ Rrs for MODIS (NASA MOBY gains) and VIIRS v02 (NRL MOBY gains); (D) Regressions Statistics (slope and r-squared) table for matchups between MODIS, VIIRS v02 and in situ Rrs measurements. Both sensors performed well for this coastal cruise (Nov. 20, 2013). MODIS produced best results (closer to 1:1 line).

Figure 5 illustrates comparisons between continuous flowthru absorption at 443nm collected onboard the NRL vessel on Nov 20, 2013 and absorption derived from MODIS and VIIRS (QAA Algorithm). The flow through data included ac-9 (absorption and beam attenuation) along a path from Bay St Louis (B) out to the Gulf of Mexico (A). These data were spatially bin averaged over a 20km track to matchup with the retrieved VIIRS ocean products at ~1km resolution. In figure 5 (left plot: distance offshore x-axis vs. total absorption at 443nm y-axis), the flowthru (black line), MODIS (red) and VIIRS (purple) absorption at 443nm are plotted across track starting at point A to point B in the top right corner. Note the VIIRS (purple) match very well with the measured (black) values yielding a regression slope of 1.04 falling closer to the 1:1 line (4 % underestimated) and a r-squared value 0.99 whereas the MODIS had a slope of 1.37 with r-squared of 0.99 respectively. Notably, the VIIRS ocean color products are doing better than MODIS in this comparison.



SLOPE	a412	a443	a488	a547	c412	c443	c488	c547
ModQAA	1.4719	1.3683	1.1459	0.8762	1.3836	1.4048	1.4270	1.4263
VIIRS QAA	0.8398	1.0374	0.9853	0.8244	1.3357	1.4410	1.4748	1.4678

R2	a412	a443	a488	a547	c412	c443	c488	c547
ModQAA	0.9968	0.9966	0.9961	0.9974	0.9875	0.9872	0.9871	0.9873
VIIRS QAA	0.9929	0.9966	0.9958	0.9965	0.9915	0.9914	0.9908	0.9909

Figure 5. The top right image snapshot shows the location of transect data taken from A to B off the coast of Mississippi. The left plot shows the matchup along the track for the IOP – 443 nm absorption products from MODIS and VIIRS using AOPS and the ac-9 in situ measurement. Continuous Flowthru samples were bin averaged to ~1km to match resolution of the satellite. The 20km track was binned to 19 valid matchups. The right plot shows the regression of satellite products against the in situ 443 nm products. The MODIS retrievals (red) were above the one to one line with a slope of 1.37 (underestimated by 37%). The VIIRS v02 AOPS retrievals (purple) used the QAA algorithm and NIR processing, all falling close the one to one line with a slope of 1.05 (underestimated by 5%).

4. CONCLUSIONS

An evaluation of the inter-comparison and accuracy of ocean color products derived from MODIS Aqua and SNPP VIIRS sensors was completed using the Navy's Automated Processing System (APS). We evaluated the differences in ocean color properties (Rrs, absorption and beam attenuation) between the two sensors and evaluated the impacts of applying vicarious gains from MOBY to the derived estimates of ocean color products. Discrepancies are thought to be attributed to imperfect atmospheric corrections, uncertainties originating from sampling errors (including pixel to point matchups and including sea surface variations), natural bio-optical variability, time differences between measured and satellite properties and common errors in coastal bio-optical algorithms (30 – 70%). Normalized water-leaving radiances and remote sensing reflectances and Inherent Optical Properties are within requirements for both the VIIRS and MODIS Aqua sensors in coastal waters.

Results show that MODIS and VIIRS derived Rrs(λ) comparisons with shipboard Rrs for both the GEOCAPE and NRL cruises are quite similar for VIIRS and MODIS Aqua and that VIIRS matchups were close to the 1:1 line with high r-squared values. The Navy applied spectral MOBY gains produced much better matchups than the original (unity gains) yielding improvements by 29% at 412nm, 19% at 443nm, 12% at 488nm, 8% at 547nm and 6% at 667nm. For both coastal cruises, VIIRS and MODIS Rrs were mostly overestimated with high slopes (0.82 to 1.18) and high r-squared values (>0.81)(see tables in figures 2 and 4). Overall the VIIRS Rrs(λ) matchups were better for the GEOCAPE cruise

(figure 2) whereas the MODIS Rrs(λ) produced better results for the NRL Cruise (figure 4). Both MODIS and VIIRS performed extremely well in these coastal environments.

For the IOP evaluation, satellite derived total absorption and beam attenuation (QAA algorithm) comparisons with shipboard measurements are similar between VIIRS v02 (with MOBY gains) and MODIS (NASA gains) and that both are performing within known standard errors. For the beam attenuation coefficient matchups, the MODIS and VIIRS v02 both produce higher errors than the absorption at all channels with VIIRS v02 giving better results. The mean error for both cruises over all four wavelengths (412, 443, 488 and 547nm) for total absorption is ~22% for MODIS and ~13% for VIIRS. The mean error over all four wavelengths (412, 443, 488 and 547nm) for beam attenuation is ~45% for MODIS and ~34% for VIIRS. Mean R-squared for all wavelengths for total absorption is ~0.97 for MODIS and ~0.96 for VIIRS. Similarly the mean r-squared for all wavelengths for beam attenuation is~0.97 for MODIS and ~0.95 for VIIRS.

Results indicate that VIIRS and MODIS are generating quality ocean color products in Northern Gulf of Mexico coastal waters for this time period. Both sensors continue to be capable of generating scientific research quality data. Continued Cal/Val procedures are required to improve coastal ocean color retrievals[5, 6]. MODIS has reached its end-of-life expectancy and VIIRS continues to have issues with degradation in radiometric calibration due to tungsten oxide build up on mirrors. As the Cal/Val teams from NASA, NOAA JPSS, and Navy continue to better characterize the sensors and monitor the trends of the calibration tables, improvements to the generated ocean products are expected.

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